

Into the Weeds: Regulating Pesticides in Cannabis

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Outside Sonoma Lab Works' otherwise ordinary building in an anonymous business park, the distinct odor of pot pervades the air. However, it's not just any pot. It is the smell of strictly regulated, professionally cultivated, rigorously tested legal cannabis. Past the heavily tinted front door, the airy 8,000-square-foot facility is filled with fluorescent light and the hum of machines. Anyone who has ever visited a university chemistry department will recognize the long, white coats.

Located on the outskirts of Santa Rosa, California, Sonoma Lab Works is one of 49 independent third-party laboratories statewide tasked with ensuring that the state's legal weed is also clean.¹ It is not a simple task. For a price of \$890 per sample,² Sonoma Lab Works will run a full panel of tests on any cannabis-based product, in accordance with strict new state regulations rolled out over the course of 2018.³

Using instruments costing hundreds of thousands of dollars each, trained technicians take high-precision measurements of potency, moisture content, residual solvents, heavy metals, mycotoxins, microbial impurities, and pesticides.⁴ Products that do not meet the state's standards cannot be sold—legally, anyway.⁵

These rules represent the best efforts of California's recently formed Bureau of Cannabis Control (BCC) to protect consumers in the state's multibillion-dollar market.⁶ However, people within the burgeoning industry and the environmental health field have widely differing views of how well the BCC regulations accomplish that goal, particularly regarding pesticides. At least one thing is clear: California's response to the challenge has implications well beyond state lines.

The Pesticide Question

In California and elsewhere, cannabis has long been grown with the help of large quantities of pesticides, including some intended only for ornamental plants and many that are associated with cancer or other serious health effects. But cannabis yields are valuable, and losing a crop to mites or mold means forfeiting many thousands of dollars. Growing plants indoors to escape detection often increases the risk that insect infestations and harmful microbes will spread quickly. For illicit growers with little knowledge of other methods and no regulatory oversight, it is easier and cheaper just to spray.^{7,8,9,10}



What is the difference between cannabis, marijuana, and hemp? They all fall under the species *Cannabis sativa* L., but “marijuana” and “hemp” are actually slang terms, not scientific names. Hemp, which is federally legal, comes from strains of cannabis that contain very low levels of the psychoactive ingredient THC (below 0.3% by weight), whereas “marijuana” refers to strains with higher levels of THC. Image: © Zbynek Pospisil/iStockphoto.

Pesticide use in agriculture is regulated by the U.S. Environmental Protection Agency (EPA) and overseen by state and local governments.¹¹ Yet because the federal government still considers cannabis an illegal drug, the EPA has not approved any pesticides for use on the plant, nor has the agency provided any indication of the level of residues on cannabis products—if any—that could be considered safe.^{12,13}

That poses a problem for California and other states across the country—nine in all at the time of publication¹⁴—that have sought to convert their illicit and medical-only cannabis programs into above-board industries with legal retail sales. These states have had to make difficult decisions about regulating the use of potentially harmful chemicals on cannabis plants without the benefit of the type of rigorous data that typically inform pesticide policy.

Perhaps unsurprisingly, no two states have come up with quite the same solution, affording consumers drastically different levels of protection, even in neighboring states.^{15,16} Beyond California's northern border, for example, Oregon requires testing for a different set of pesticides and enforces different limits for residue levels on cannabis products. In some cases, Oregon's limits are tighter than California's; in others, they are more

lenient.¹⁷ Cross another border into Washington, where recreational cannabis sales began in 2014,¹⁸ and pesticide testing is not required at all.¹⁹

The average consumer, meanwhile, often is left with nothing more than vague assurances of safety from sellers and regulators—and little sense of the uncertainty behind the scenes. “Most consumers have this general assumption that if something is on a shelf and for sale, and they are paying sales tax, then it is safe,” says Jill Lamoureux, a Colorado-based cannabis consultant, grower, and entrepreneur. “But the way states are doing this is very arbitrary, and it is not backed by science at all.”

Buyers may feel some consolation that any pesticide regulations are better than none—and that in even the least-rigorous regimes, cannabis users likely have access to cleaner pot today than ever before. However, is it clean enough? What is truly safe? In addition, and just as important, how can governments entice consumers and growers to participate in the legal market rather than the cheaper black market, which lacks safety protections entirely? There are no easy answers. Therefore, states continue to experiment with policy, as public health hangs in the balance.



THC is found in the female cannabis flower. The female flowers produce a sticky resin to capture pollen from the male plant. In high-THC varieties, this resin is packed with the psychoactive compound. The most potent cannabis is produced when the female flower is not pollinated and thus does not divert energy to producing seeds. The color of the resin alerts farmers when THC content has reached its maximum. At that point, the ripe flowers are harvested, dried, and cured. They can either be smoked or further processed into tinctures, concentrates, edibles, and other products. Image: © Canna Obscura/Shutterstock.

California's Approach

Taken as a whole, California's pesticide regulations for cannabis are considered by most industry watchers to be the strictest in the country. California has the advantage of a sophisticated Department of Pesticide Regulation (DPR) with significant expertise in toxicology and human-health risk assessment.^{20,21} In some cases, that expertise—paired with broad support for environmental regulation—has helped the state establish rules governing pesticide use that are stricter than those set by the U.S. EPA.²²

California drew on these resources to develop pesticide-residue limits for cannabis that it considers protective of public health, says DPR spokesperson Charlotte Fadipe. The process was anything but straightforward, however, given an almost total lack of reliable data on cannabis consumption in the state, subsequent pesticide exposure, and potential health effects associated with inhaling smoke or vapor from contaminated pot. Further complicating the issue is the federal status of cannabis as an illegal Schedule I drug.

Any pesticide purchased in the United States is labeled by the EPA for specific crop uses. Labels also note the approved application rates and timing, as well as required worker safety precautions.²³ Use of any pesticide in a way not authorized on the label is illegal.

Because no pesticides have been registered for use on cannabis,²⁴ California law states that, officially, a pesticide product can be used on cannabis only if its active ingredient meets specific criteria. Namely, the ingredient must be exempt from federal residue tolerance requirements and either exempt from federal registration requirements or registered for a use that is broad enough to include use on cannabis plants. Pesticides that meet these criteria, such as sulfur, neem oil, and *Bacillus thuringiensis*, are also common in organic agriculture.²⁵

However, at the same time, California has accepted the reality of pesticide use on pot—as well as the potential for overspray from neighboring farms and contamination of other ingredients in cannabis edibles (foods and drinks that are infused with cannabinoids). The state has therefore imposed limits, rather than outright bans, on some pesticide residues in cannabis products.

The first step in the process of setting these limits was to consult with cannabis growers and regulators in other states that have legal markets, such as Washington and Colorado, to develop a list of pesticides that have been commonly used on the crop and could be screened for by state-certified third-party laboratories. In the end, the DPR arrived at a list of 66 pesticides. Twenty-one of these are classified as Category I pesticides, meaning they are banned for use on cannabis because they either are not registered for use on food crops or are known to pose a significant risk to groundwater.²⁶ For these compounds, any detection constitutes a failure and keeps the product off store shelves.³

For each of the other 45 chemicals on the list, which are classified as Category II pesticides, the DPR calculated separate action levels for both ingestible and inhalable products. In effect, a grower may still be able to apply these pesticides under certain conditions, according to David Chen, lab director at Sonoma Lab Works. As long as residue levels in the finished product fall below prescribed limits, the product is considered safe enough to sell.³

Among the pesticides with allowable residues is the insecticide bifenthrin, classified by the EPA as a possible human carcinogen and shown in animal studies to have endocrine-disrupting properties.²⁷ Bifenthrin is applied to conventional crops including corn, raspberries, and hops,²⁸ and, in the cannabis world, is commonly used to “bomb” indoor grow rooms to kill spider mites between cultivation cycles.¹⁰ The Category II list also includes the organophosphates acephate and diazinon, used to control pests on cannabis as well as on a variety of conventional fruit,

vegetable, nut, and field crops. These chemicals are highly neurotoxic to birds and beneficial insects.^{29,30} Acephate also is neurotoxic to humans and a possible human carcinogen and potential endocrine disruptor.³¹

State toxicologists determined residue limits for ingestible vs. inhalable products using vastly different approaches, explains DPR senior toxicologist Svetlana Koshlukova. For foods, drinks, and tinctures, the state drew on pesticide reference doses established by the U.S. EPA³² and other national and international regulatory agencies. State toxicologists also estimated maximum consumption of cannabis in all forms in lieu of any meaningful data.

Koshlukova says that the DPR considers its action levels for ingestible products to be health-based because the department uses data on toxicity and human exposure, something no other state can yet claim. Because California's rules call for testing of the final, processed edible product—as opposed to only the cannabis-derived portion—these limits also account for potential pesticide contamination of other ingredients, such as flour or sugar.

For inhalable products, including cured flower products for smoking and highly concentrated extracts for vaporizing, the state faced a total lack of toxicity data because pesticide reference doses are based on ingestion, not inhalation (with or without heating). The department turned instead to values published by the French agency CORESTA in 2016³³ for what might remain on tobacco plants after applying “good agricultural practices” and using the least amount of pesticide that would prevent infestation.

“For cannabis that is smoked or vaped, there is no specific data that we can use to generate health-based numbers, absolutely none,” Koshlukova notes. “As such, we provided the Bureau [of Cannabis Control] with levels that do not incorporate toxicological considerations.”

Has California Gone Far Enough?

What most sets California apart from each of the other states that have legalized adult-use cannabis sales to date, however, are not the minutiae of its regulations. Rather, it is the sheer scope of California's influence on cannabis policy, safety, and consumption nationwide.

Given the state's reputation as a health policy trendsetter and a model of environmental regulation, other states seeking to update or develop new regulations—and potentially even the federal government—could well look to borrow from California's cannabis laws, suggests Chris Hudalla, founder and chief scientific officer of ProVerde Laboratories, a cannabis testing lab serving Massachusetts and Maine.

California also is the economic and cultural home of illicit cannabis in the United States, with a still-thriving black market³⁴ and potentially massive exports of surplus production to other states.⁶ On top of that, with 39.5 million residents and first-year sales totaling \$2.5 billion, California represents the world's largest market for legal cannabis.³⁵

As such, some experts are concerned that the state has not gone far enough in protecting the public from harmful pesticides. Among them is Jay Feldman, executive director of the Washington, DC, nonprofit Beyond Pesticides. In particular, he says, the DPR's calculation of allowable residues on ingestible products lacks a key scientific consideration. “If this were registered under a federal system, what the agency would have to do is perform an aggregate risk assessment for chemicals that have a common method of toxicity,” he notes.

Organophosphate pesticides, for example, all act on the brain in a similar way. Dozens of them are registered for use in the United States, and four appear on California's Category II list of pesticides permitted below certain thresholds on cannabis. According to a

2013 U.S. EPA report, because of this shared mechanism, exposure to a single organophosphate chemical by multiple routes—or to multiple organophosphates by multiple routes—may lead to “serious additive toxicity.”³⁶

“If [the DPR] does not have this kind of data, which is extremely expensive to produce and to evaluate, then it should use its statutory authority to embrace a precautionary approach,” Feldman says. This argument is especially valid because individuals who use cannabis for medical reasons may be more vulnerable to pesticide-related health effects due to a compromised immune system or underlying chronic disease. “They are establishing a false sense of security regarding the allowed residues, given that they have not looked at the aggregate cumulative risk of dietary and nondietary exposure in combination with cannabis residue,” he says.

The state’s cobbled-together residue limits for inhalable products represent an even larger issue, within California and across the industry. As the DPR acknowledges, very little is known about what happens chemically when pesticides are heated—and potentially broken down into other hazardous compounds—let alone the potential health effects of such exposures.

This lack of knowledge is due in part to the illegality of cannabis at the federal level. However, it also stems from the fact that information about pesticide exposures via smoked tobacco is virtually nonexistent. That’s no accident, says Holly Johnson, chief science officer at the American Herbal Product Association and a member of the U.S. Pharmacopeia’s Medical Cannabis Expert Panel.

“In theory we should be able to look to the tobacco industry for guidance, but there is actually not much helpful data there,” Johnson says. “Since some studies have shown [cigarette] filters absorb a significant amount of pesticides in tobacco smoke, and due to the other inherent risks associated with tobacco use, pesticide exposure in tobacco smokers has not really been addressed.”

Filters are typically not used when smoking marijuana. Yet the data blackout persists, with potentially serious implications for public health, says Ethan Russo, director of research and development for the Prague-based International Cannabis and Cannabinoids Institute.

“Many of these agents are accumulative in their effects, particularly with the potential carcinogens,” Russo says. “We don’t know what’s going to happen down the road, ten to twenty years later, due to exposure to these agents. Just because somebody smokes something and doesn’t notice any untoward effects doesn’t mean that it’s safe. It’s a sort of creeping danger.”

Furthermore, inhaling is generally considered the most sensitive exposure pathway in the human body, says pesticide consultant Chuck Benbrook, a visiting professor at England’s Newcastle University. “When you ingest pesticides in food, those residues have to make it all the way to your GI tract and down into the lower intestines until they can get picked up by the bloodstream,” Benbrook says. “For most pesticides, a small percentage of ingested residues reaches the bloodstream. But most of the residue that’s drawn into the lungs is going to move directly into the blood. It is a much more potent route of exposure.”



California is the economic and cultural home of illicit cannabis in the United States, with a thriving black market and potentially massive exports of surplus production to other states. It is also the world’s largest legal pot market; in the first year after recreational use was allowed in 2016, the state saw sales totaling \$2.5 billion. Image: © ZUMA Press, Inc./Alamy Stock Photo.

A single study, published in 2013, found evidence that pesticide residues on the cannabis flower are transferred very efficiently into smoke—and thus to the user—after being combusted. Using a smoking machine, the California-based researchers demonstrated that 60–70% of residues present on the flower ended up in the smoke after burning in a glass pipe.³⁷

The Canadian Model

Given these risks, Feldman argues that the most appropriate response is to enforce zero tolerance for pesticides across the board—and not merely for a subset of the testing panel. “Under the banner of medical marijuana, we’re dealing with sensitive populations that have preexisting conditions; they may have neurological issues, there may be seizure patients, there may be cancer patients,” he says. That possibility calls for a precautionary approach, he argues: “This particular commodity should be treated as requiring organic production because of the limitations of our knowledge and the uncertainties and the population groups that are affected.”

No U.S. states have yet adopted such a policy. However, for a model of true zero tolerance, Californians need to cross just one more border to the north, from Washington to Canada, which in October 2018 became the second nation in the world (after Uruguay in 2013³⁸) to legalize cannabis.³⁹

Canada’s current pesticide regulations, which went into effect on 2 January 2019, require testing for a total of 96 compounds.⁴⁰ That’s 30 more than in California, reducing the

likelihood that unscrupulous growers will get away with applying harmful chemicals that they know will not be detected.

Additionally, most of Canada’s residue limits are far lower than California’s. Across the board, they are based not on potential health risk but rather on the lowest concentration at which residues can be reliably quantified using modern technology, also known as the limit of quantification. That level is often as low as 0.01 ppm.

There are practical reasons to believe that Canada’s approach will not work in California, however. For one thing, according to Hudalla of ProVerde Laboratories, it could all but preclude the use of outdoor cultivation, which is widely practiced in Northern California’s famed “Emerald Triangle” pot-growing region.⁴¹ In Canada, although outdoor growing is technically legal, the government has yet to approve any specific projects.⁴² Instead the country’s cannabis comes from greenhouse and indoor grows, which can be more tightly controlled.

“There are pesticides in our environment, everywhere, to some low level,” Hudalla says. “This is especially true for big agricultural environments” like California, where much of the nation’s produce is grown. “Even if a pesticide is not in use, if a neighbor is using pesticides, the drift can contaminate neighboring crops. In addition, the EPA has determined that some pesticides are environmentally mobile and can appear in groundwater as well as rain.”

Outdoor cannabis crops can become contaminated with pesticides that the growers never actually applied—sometimes at levels high enough to trigger a failed test. Chen of Sonoma Lab Works says that such cross-contamination is not just a theoretical scenario;



Inhaling is potentially the most sensitive exposure pathway in the human body. “For most pesticides, a small percentage of ingested residues reaches the bloodstream,” explains pesticide consultant Chuck Benbrook. “But most of the residue that’s drawn into the lungs is going to move directly into the blood.” Image: © Charles Wollertz/iStockphoto.

he's seen it happen to his own customers in California. "Several streams of unintentional contamination that are common to farmers are overspray from neighboring acres due to factors such as wind or recycled water," he says. "When working with such small concentrations, there are dozens of avenues of contamination."

Moving cultivation indoors to avoid incidental contamination, however, comes with its own set of consequences, including increased energy and water consumption, Hudalla notes. This type of cultivation can drive up costs for growers, as can the tighter testing requirements of a zero-tolerance policy: When residue limits go down, costs for equipment, personnel, and laboratory reference standards go up.

"These costs will eventually be added on to consumers," Hudalla says. "As the price of regulated cannabis goes up, consumers will transition back to [illegal] suppliers."

According to Chen, the cost of mandatory testing in California is already high enough to steer some longtime growers away from the legal market. In an effort to help stimulate legal sales and stamp out the robust black market after 2018 tax receipts fell far short of expectations, state lawmakers proposed slashing fees and taxes currently paid by both growers and consumers.⁴³

Meanwhile, in the state of Washington, where regulators are considering mandating testing for the first time since legal sales began more than five years ago, growers have expressed similar concerns about the effect of additional costs on their bottom line.⁴⁴ According to grower Jade Stefano of Washington's Puffin Farm, independent farmers like her who are dedicated to costlier pesticide-free production could be among those hurt first in her

state's oversupplied market. "Most of the producers are struggling right now financially with super-low prices, so adding another cost on top of everything else is definitely going to put some more people out of business, many of whom are totally organic, legitimate producers," she says.

What Comes Next?

Beyond the added costs of indoor farming and stricter testing, consumers have another reason to be cautious when comparing residue limits: Canada does not yet allow edible products, just cannabis flower and oil-based extracts. This prohibition means that, unlike in California, Canada's limits do not account for potential contamination via other food ingredients.

Nearly all the pesticides on California's Category II list have substantial agricultural uses, Benbrook says. Residues could well be present on conventional food products, whether from contamination or direct application. As a result, even if the cannabis itself is completely clean, limits as low as Canada's for edible products would likely trigger high failure rates in California.

Residues on edible products present a regulatory dilemma that Canada will face shortly, as Health Canada, the agency overseeing its cannabis rules, gears up to legalize edibles by October 2019.⁴⁵ The agency has yet to reveal how it plans to regulate pesticides on such products, says Jodi McDonald, president of the Alberta-based cannabis testing lab Keystone Labs.

If Health Canada decides to require testing of final, processed food products as California does, some built-in allowance may



Canada takes a zero-tolerance stance on pesticide residues on cannabis. For variety of reasons, the country's cannabis comes from greenhouse and indoor grows, allowing plants to be protected against pesticide drift. However, this also means growers use more electricity and water to produce their crops than would be required for outdoor cultivation. Image: © Bloomberg/Getty Images.

have to be made for potential contamination of other ingredients. “To be able to meet the current pesticide limits for Canadian cannabis in edibles will certainly be a difficult hurdle for producers to clear,” says McDonald.

California may also revise its pesticide regulations in the future, notes Fadipe. The DPR has commissioned a study of cannabis consumption using in-person surveys at dispensaries, which will provide regulators reliable data for the first time about how people are using cannabis and in what quantities across different demographics and levels of susceptibility.

Findings will be available no sooner than the end of 2020 and could call for either lower or higher residue limits, Fadipe says. “Depending on what this survey tells us, we may have to adjust levels,” she explains. “It may mean more [pesticides] can be used, it may mean less can be used. We just do not know at the moment.”

By then, perhaps, the next question may be whether the federal government is preparing to legalize cannabis—as it recently did with hemp, pot’s nonpsychoactive cousin.⁴⁶ If so, how will it decide to manage pesticide use and residues? Will regulations look like California’s, or Canada’s, or something in between? And what will be the state of the science informing these regulations?

“Down the line we’d like to see federal change in the next hopefully five to ten years,” says Sonoma Lab Works senior scientist Luke Khoury. “I think that’s when we’ll see a push to say, ‘Let’s get definitive answers on what these levels should be and which compounds really provide the highest risk to consumers.’”

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